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NATIONAL MARINE FISHERIES SERVICE

Blue Crab Meat
I. Preservation by Freezing
II. Effect of Chemical Treatments on Acceptability

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SPECIAL SCIENTIFIC REPORT–FISHERIES No. 630

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I. Preservation by Freezing
II. Effect of Chemical Treatments on Acceptability

By

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and FREDERICK J. KING

Special Scientific Report—Fisheries No. 630

Seattle, Washington
July 1971

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Blue Crab Meat
I. Preservation by Freezing[1]

By

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ABSTRACT

Freezing was studied as a method of preserving blue crab meat for up to 8 months. The results indicate that a rapid freezing rate, storage below 0° F, and vacuum packaging are preferable to minimize losses in the desirable qualities of freshly picked meat.

INTRODUCTION

The blue crab (*Callinectes sapidus*) is one of our most valuable commercial shellfish resources both in volume of landings and in value of its food products. This industry is also distinguished by having one of the greatest seasonal variations in ex-vessel prices for any shellfish. Several factors are involved, such as the short life span of the animal (2-3 years) and the fact that it must be kept alive until cooked in order to remove the meat. However, a more significant factor is that blue crab meat itself is a highly perishable product. Practically all of the present output is sold as fresh meat which has a shelf life of up to 10 days at 32° to 38° F.

Because blue crab meat is highly perishable, several methods of food preservation have been considered. Heat sterilization was proposed several years ago (Fellers, 1936) but this treatment is unpopular because it causes discoloration and development of off-flavors. Although the chemical nature of these alterations is not completely understood, it is generally accepted that heat-induced breakdown products from the muscle proteins and copper from blood pigments are involved (Groninger and Dassow, 1964; Elliott and Harvey, 1951). Milder heat treatments have been proposed (Byrd, 1951) and heat pasteurization is used commercially. By using heat to reduce the bacterial population of freshly picked crab meat, it is possible to extend the meat's storage life for up to 6 months at 33° to 38° F (Littleford, 1957). In practice, the heat input to reduce the bacterial population has to be controlled very carefully to avoid the undesirable effects of overcooking on the meat's appearance and taste. Because the tolerance is narrow between the intended and the undesirable effects of this heat treatment, the usefulness of this method of preservation is highly dependant on the bacterial population of the meat just before it is pasteurized.

[1] Presented at the 30th Annual Meeting of the Institute of Food Technologists, May 24-28, 1970.

Freezing has also been considered as a method of preservation. Since it achieves inactivation of bacterial spoilage without a heat treatment, it has a theoretical advantage compared with pasteurization. However, the commercial production of frozen blue crab meat is minor since its storage life at 0° F is considered to be less than 1 month (U.S. General Services Administration, 1956). If blue crab meat is frozen by conventional techniques (plate freezer, air-blast freezer, etc.), the meat tends to become spongy and fibrous in texture and it will lose the delicate flavor of fresh meat after a few weeks at 0° F (Dassow, Pottinger, and Holston, 1956). Although this deterioration is probably related to protein and lipid transformations in situ, its cause is not clear. Similar phenomena are believed to limit the frozen storage life of other crustaceans although the rate of this deterioration is dependent on the species used and whether the picked meat or meat-in-the-shell is frozen.

It is well known that the storage stability of frozen seafoods, in general, can be influenced by the following factors: method (rate) of freezing, method of packaging, and storage temperature and its duration. For example, it is known that techniques such as cryogenic freezing (vs. plate, air blast, or brine immersion freezing), vacuum packaging (vs. a loose-fitting package containing air) and storage below 0° F (vs. storage at 0° F or above) may prolong the storage life of seafoods. In the case of blue crab meat or meat from other crustaceans, the relative importance of these techniques in determining frozen storage stability has received very little attention. Consequently, the objective of the present investigation is to compare each of these techniques in various combinations with other preservation techniques in order to discover which procedures are required to preserve blue crab meat for 2 to 8 months without any significant loss in the desirable qualities of freshly picked meat.

MATERIALS AND METHODS

Types of Blue Crab Meat

Most of the experimental program was performed with "regular" blue crab meat obtained from low-salinity waters in the Chesapeake Bay and supplied by the J. M. Clayton Company, Cambridge, Md. Regular meat is a trade designation for meat which is picked from crab bodies or cores. Because it contains mostly flake meat with a much smaller quantity of lump meat, it is called "flake" meat in this report. For comparison purposes, hand-picked lump meat and claw meat from the same source were used in smaller quantities. For other comparison tests, regular and lump meat were obtained from the high-salinity waters off the Virginia coast and supplied by George O. Spence and Sons Co., Quinby, Va. The freshly picked samples were shipped in ice to the National Marine Fisheries Service Laboratory in College Park, Md., and immediately frozen as described below. Each sample in these tests contained approximately 95 g of crab meat. After completing the preservation treatments, the samples were shipped to FMC Central Engineering Laboratories in insulated styrofoam containers using dry ice for the frozen samples or wet ice for the freshly picked control samples.

Freezing of Blue Crab Meat

Two cryogenic liquids, Freon 12[2] and nitrogen, were used to freeze individual pieces of meat before packaging. These cryogenic methods were not used on prepackaged meat for two basic reasons. We were aware that prepackaging the meat would increase the cost of freezing per unit of meat frozen since it would lengthen the time needed to freeze all the pieces of meat in that package. Also, there was no evident advantage from a technological viewpoint for the blue crab industry to freeze prepackaged meat. Indeed, preliminary experimental results have indicated that the quality of individually frozen pieces of blue crab meat is superior to the quality of prepackaged frozen blue crab meat even when the package is kept ¼-inch thick during freezing.

Freezing by immersion in food grade Freon 12.—The arrangement of the equipment is shown in Figure I-1. Dewar I (capacity 2 liters) was used to cool the Freon coming from

[2] Trade names are used to facilitate description; no endorsement of product is implied. The chemical name for Freon 12 is dichlorodifluoromethane.

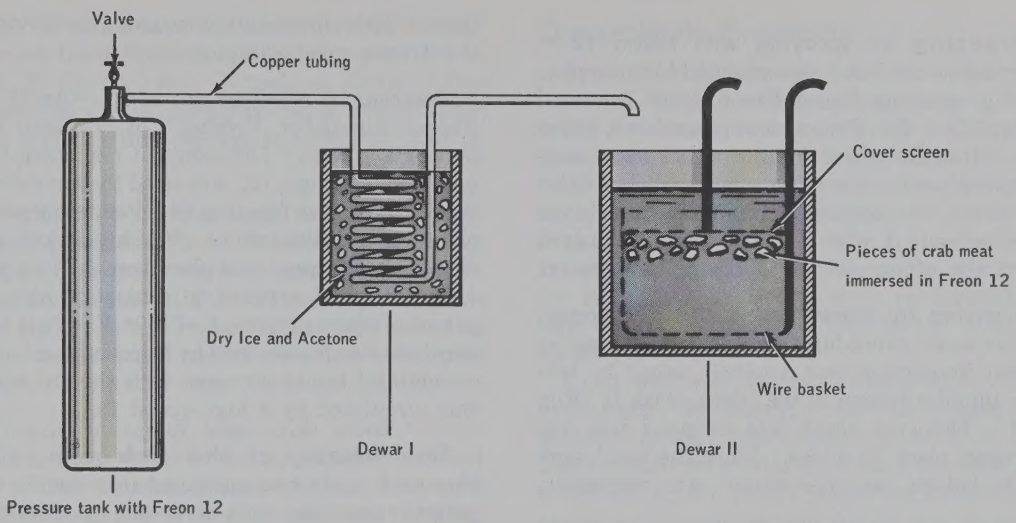

Figure I-1.—Equipment used for immersion freezing tests.

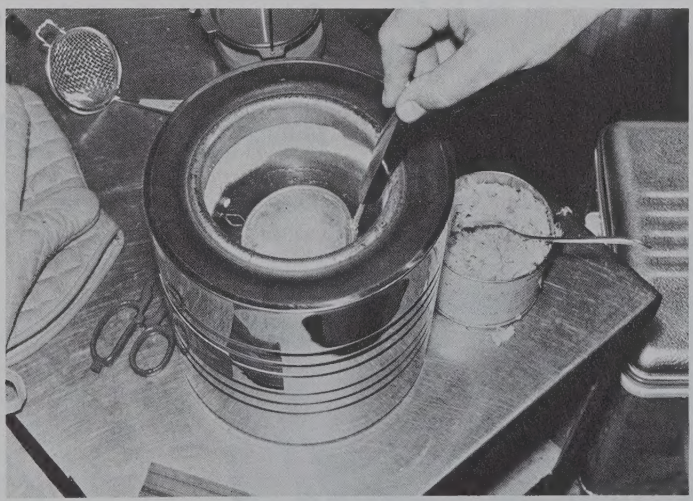

Figure I-2.—Immersion freezing of crab meat in food grade Freon 12.

the tank by means of a dry ice-acetone mixture. The liquid Freon level in Dewar II (capacity 4 liters) was kept at about 4 inches (Fig. I-2). The highest temperature the liquid Freon can reach is —21.6° F, which is its evaporation temperature. Owing to the evaporative cooling effect, the temperature of the Freon in Dewar II was usually several degrees lower.

A stainless steel wire basket was first immersed into the Freon. Each 95-g sample was frozen by dropping the crab meat, piece by piece, into the Freon. This operation took 60 sec to complete. Then a screen was placed on top of the floating meat pieces to hold them immersed. The meat was taken out of the Freon by means of the wire basket and placed into its package.

Freezing by spraying with Freon 12.—A spray nozzle head was attached to the copper tubing carrying liquid Freon from Dewar I (Fig. I-1). The Freon was sprayed in a swaying action for about 6 min onto a crab meat sample placed on a stainless steel screen. After the meat was covered with another stainless steel screen, it was turned over and sprayed from the other side until completely frozen.

Freezing by immersion in liquid nitrogen.—The same procedure as used in freezing by Freon immersion was applied, using in this case liquid nitrogen in the Dewar flask II (Fig. I-1). The crab meat was dropped into the nitrogen piece by piece. Since the meat sank to the bottom, no cover screen was necessary.

Freezing by intermittent dipping in liquid nitrogen.—The crab meat was spread as loosely as possible in the wire basket and then the basket was immersed in the liquid nitrogen. However, the liquid nitrogen immersion was interrupted in short intervals to allow the inside of the sample to equilibrate in temperature. This was done by dipping the sample 10 times in 30 sec, with an immersion time of 2 sec each time. This procedure prevented cracking of the frozen meat samples.

Freezing by nitrogen gas blast.—An "Ultra Freeze Simulator Freezer" of National Cylinder Gas (NCG) Division of Chemetron Corporation, Chicago, Ill., was used to demonstrate the effect of fast freezing in a low-temperature nitrogen gas atmosphere. Freshly picked, regular blue crab meat was placed on a wire screen (Fig. I-3) and exposed to a blast of nitrogen gas at a temperature of —150° F. This temperature was maintained by injecting controlled amounts of liquid nitrogen into the gas which was circulated by a high-speed fan.

Slow freezing of blue crab meat. — The blue crab meat was packaged in a double wall polyethylene bag, then wrapped by aluminum foil and a paper bag. The different samples were then placed in a —20° F freezer room.

Other Methods of Preservation

Pasteurization of blue crab meat. — Vacuum-packed pouches (6.5 × 10 inches) containing 95 g of crab meat were submersed into

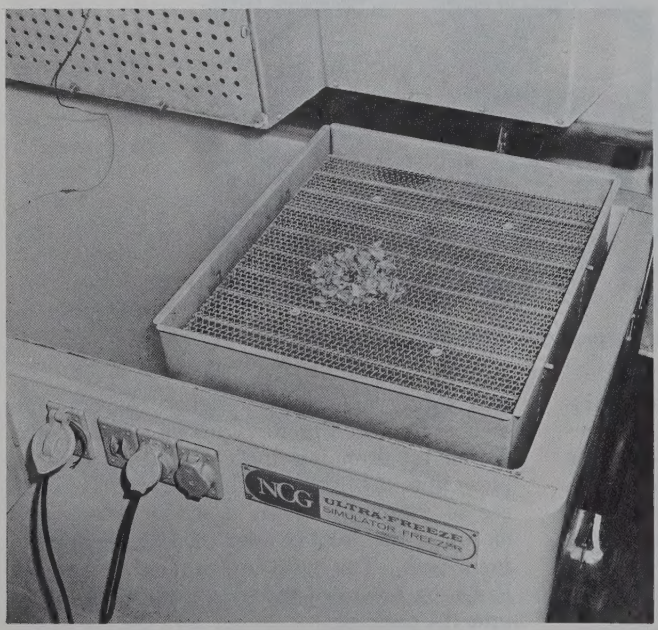

Figure I-3.—Crab meat spread on the screen of an "Ultra-Freeze Simulator Freezer".

a 170° F water bath and kept there for 10 min to raise the minimum internal temperature to 170° F (Byrd, 1951; Littleford, 1957). The hot pouches were quickly cooled in a cold-water bath and put into storage in a refrigerator at 34° F.

Sterilization of blue crab meat.—Vacuum-packed pouches (6.5 × 10 inches) containing 95 g of crab meat were brought into an autoclave and heated at 250° F under steam pressure for 15 min. The pouches were cooled to room temperature under pressure with cold water. Then they were stored at 34° F.

Freeze drying of blue crab meat.—Crab meat samples were frozen by exposure to cold air (—20° F) then freeze-dried at a vacuum of less than 200 μ and a maximum heating temperature of 120° F. The freeze-dried samples were packaged under vacuum in laminated pouches.

Methods of Packaging and of Storage

Vacuum pouches.—All the heat-processed and freeze-dried crab meat samples and some of the frozen samples were packaged in pouches of 6.5 × 10 inches made of laminated polyethylene-aluminum foil-mylar and heat-sealed under a vacuum of 28 inches.

Bags.—The rest of the frozen crab meat samples were placed into double-wall polyethylene bags which are commonly used for storage of food in household freezers. The bags were wrapped with aluminum foil for mechanical protection and as a protection against "freezer burn" which is caused by a moisture transport because of uneven temperature distribution inside the bag. An outside paper bag was used to facilitate labeling.

Storage conditions.—Most of the frozen crab meat samples were stored at —20° F (± 2° F) or at 0° F (± 2° F). A few samples were stored on dry ice (—108° F) for comparison purposes. The pasteurized and sterilized samples were held at 34° F (±2° F) while the freeze-dried samples were held at ambient (room) temperature.

Organoleptic Evaluation

From an initial group of 24 persons, a taste panel of 12 to 15 members was selected. Each tester was asked to rate samples for appearance, odor, texture, and overall taste on a 9-point hedonic preference scale. For the flavor evaluation, intensity scoring, and descriptive evaluation were also used (Fig. I-4). To lessen the effect of fatigue, only five samples were used for each test. Two tests were performed per day, one at about 11:30 AM and the other at about 3:00 PM.

Crab meat samples were prepared for these evaluations by thawing in the package at ambient (room) temperature for 45 to 60 min. The pasteurized or sterilized samples were just taken out of the pouch while the freeze-dried samples were rehydrated for 25 min in water at ambient (room) temperature and drained afterwards. Samples were distributed into 1-oz portion control cups and served to the members of the taste panel.

Fresh crab meat was used as a reference sample for each panel session. It was shipped in crushed ice by air freight from the East Coast, stored at 34° F and used within 1 week. It was served together with the other samples being evaluated and was not designated as being "fresh."

RESULTS AND DISCUSSION

Evaluation of Taste-Panel Consistency

Since fresh crab meat was used as an unknown reference sample in each session, the panel evaluated it a total of 23 times during an 8-month period. The total average ratings for these fresh samples (based on 23 evaluations or 295 individual ratings) were: appearance = 6.6, odor = 6.5, texture = 6.6, overall taste 6.8, and degree of undesirable flavors = 1.5. The ranges for these ratings were: appearance = 5.5 to 7.4, odor = 5.7 to 7.9, texture = 5.9 to 7.5, overall taste = 6.4 to 7.4, and degree of undesirable flavor = 1.1 to 1.8.

A statistical analysis was made from the individual ratings for overall taste to assess the effects of personal preference for crab meat and individual sensitivity to different samples of fresh crab meat on the results (Strasser, 1969).

BLUE CRAB STUDY

Name _____ Date _____ Time _____

Please evaluate each crab meat sample for the quality factor listed below, using the appropriate scale.

Appearance	Odor	Texture	Overall Taste
Like extremely	9		
Like very much	8		
Like moderately	7		
Like slightly	6		
Neither like nor dislike	5		
Dislike slightly	4		
Dislike moderately	3		
Dislike very much	2		
Dislike extremely	1		

Presence of Undesirable Flavor		Kind of Undesirable Flavor	
None	1	Flat	1
Slight	2	Salty	2
Moderate	3	Too acidic	3
Intense	4	Metallic	4
		Medicinal	5
		Bitter	6
		Astringent	7
		Rancid	8
		Musty	9
		Biting	10
		Fishy	11
		Other (Please state)	

SAMPLE	Appearance		Odor		Texture		Overall Taste		Presence of Undesirable Flavor	Kind of Undesirable Flavor
	Rating	Remarks	Rating	Remarks	Rating	Remarks	Rating	Remarks		
A										
B										
C										
D										
E										

Figure I-4.—Rating sheet for organoleptic evaluation of quality.

The results of this analysis indicated that it was not necessary to apply statistical corrections to the overall taste data. Following this analysis and visual examination of the taste-panel data (Strasser, 1969), it was decided not to apply statistical corrections to the appearance, odor, and texture data as well.

Several different chemical or physical methods have been used or proposed to determine the quality of crab meat from various species. They include determination of ammonia (Burnett, 1965; Fernandez-Flores and Salwin, 1968), trimethylamine nitrogen or volatile basic nitrogen (Spinelli, Eklund, and Miyauchi, 1964a; Tanikawa, 1959), volatile reducing substances (Farber and Lerke, 1968), picric acid turbidity (Kurtzman and Snyder, 1960), 2-thiobarbituric acid (Anderson and Danielson, 1961), hypoxanthine (Spinelli, Eklund, and Miyauchi, 1964b), physical measurement of shear force (Dassow, McKee, and Nelson, 1962), or drip (Barnett, Nelson, and Dassow, 1967; Collins and Brown, 1965; Miyauchi, 1963). They were not used in this investigation owing to incomplete information on their suitability for assessing degrees of freshness of thawed blue crab meat (in contrast to fresh meat) or their correlation with sensory evaluation methodology as recommended by Amerine, Pangborn, and Roessler (1965). A similar conclusion was made by Early (1967).

Comparison of Freezing Rates

In order to compare freezing rates, pieces of lump meat of about 5 mm diameter, 20 mm in length and about 1 g in weight were exposed to three different freezing conditions. These conditions were freezing in still air at —20° F, freezing in circulated nitrogen gas which was kept at —150° F, and immersion freezing in Freon 12 which had a temperature of —28° F. The temperature in the center of the piece of crab meat, as measured by fine copper-con-

stantan thermocouples, was monitored continuously during the freezing experiments. The results are plotted in Figure I-5. It took approximately 30 sec to freeze the sample by immersion in Freon 12. The freezing time was approximately 2 min when using cold nitrogen blast. However, it took 14 min to freeze the same size piece in still cold air. Immersion proved to be by far the fastest method of freezing.

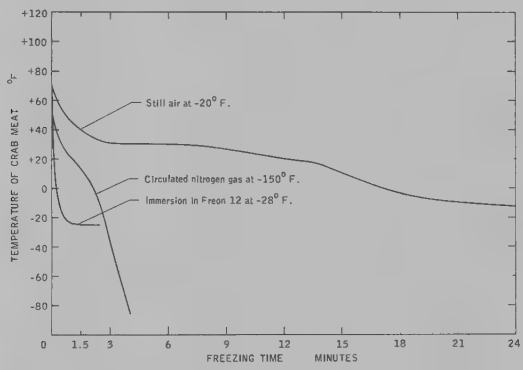

Figure I-5.—Freezing curves of crab meat.

Comparison of Different Freezing Methods

Ratings obtained from samples frozen by Freon immersion or by Freon sprays were quite similar to those obtained from samples frozen by intermittent immersion in liquid nitrogen (Table I-1). In a few cases, the ratings in these tables also suggest that samples frozen in Freon were slightly better than samples frozen in liquid nitrogen but this difference is not considered significant.

In comparison with the Freon freezing and the liquid nitrogen freezing methods, the panel ratings for samples frozen by a cold nitrogen gas blast (about —150° F) were very similar for up to 4 months' storage. After 6 months' storage, the samples frozen by nitrogen blast rated slightly, but not significantly, lower than the immersion-frozen samples (Table I-1).

Results obtained from panel evaluations of slow-frozen samples indicate that this method was less desirable than any of the other freezing methods used in this study. For example, even a low-temperature storage at —20° F did not prevent a gradual loss in quality in these samples, whereas the quick-frozen samples maintained a much better quality at this temperature. These results are consistent with the hypothesis that slower freezing rates permit more interactions between solutes in the unfrozen tissue fluids and other tissue components (Love, 1968; van den Berg, 1968).

Although most of the frozen-stored samples were slowly thawed at room temperature, quick thawing by microwave energy resulted in a product of slightly higher acceptability (Table I-1).

Comparison of Freezing with Other Preservation Methods

Panel ratings given to heat-pasteurized samples stored for up to 8 months at +34° F (Table I-2) were generally comparable to quick-frozen, vacuum-packaged samples stored at 0° F for the same length of time. In some instances, the ratings for these pasteurized samples appeared to be lower than those received by samples stored at —20° F (Table I-1). On the other hand, heat-sterilized samples were consistently downgraded by the panel for their undesirable bluish discoloration as well as their off-taste (Table I-2).

A few samples of crab meat were preserved by freeze-drying, vacuum-packaged, and stored for 6 months at ambient temperature. The panel consistently rated the taste of these samples as unacceptable although their appearance and texture received fair acceptance ratings (Table I-2).

Effect of Different Storage Temperatures

Crab meat samples held at dry ice temperature (about —108° F) were rated highly by the taste panel even after 8 months' storage. Quick-frozen samples held at —20° F were rated somewhat lower during this storage period but their ratings were still generally within the range given to freshly picked, nonfrozen control samples. In contrast, some of the samples held at 0° F, received much lower ratings than comparative samples held at the lower temperatures. Particularly, the ratings of

texture often dropped farther than the taste ratings for these samples. Evidently, the method of packaging as well as the length of the storage period significantly affects the quality of samples held at 0° F for up to 8 months.

Comparison of Two Packaging Methods

It was generally noted that the samples which had been packaged in a vacuum-sealed pouch (laminated polyethylene-aluminum foil-mylar) rated higher than samples which had been packaged in unsealed polyethylene bags under atmospheric pressure. In samples stored at —20° F, this difference was more pronounced in the odor ratings than in the taste ratings. In samples stored at 0° F, this difference became obvious in the taste ratings after much shorter storage periods.

Comparison of Types of Blue Crab Meat

In evaluating the results of the taste-panel evaluations (Tables I-1 and I-2), flake and lump meat samples have been considered on virtually synonomous terms. Lump meat is often regarded as a premium grade of flake meat in the trade. The freezing and storage characteristics of both types of meat appear to be reasonably similar. On the other hand, claw meat is considered a lower quality meat even when fresh since it comes from a muscle tissue which has a different physiological function. Thus, the poorer ratings given for the few frozen-stored claw meat samples tested (Table I-1) are not surprising. The taste-panel evaluations did not reveal any consistently significant difference that could be related to the low-salinity waters of the Chesapeake Bay and the high-salinity waters off the Virginia Coast. This conclusion may surprise some gourmets who are partial to locally caught blue crabs but the origins of this partiality are speculative.

SUMMARY AND CONCLUSIONS

The results of this investigation show that rapid freezing, storage below 0° F, and vacuum-packaging extend the shelf life of blue crab meat. Quick-freezing methods (immersion or spraying using Freon 12 or low-temperature nitrogen) were superior to slow-freezing methods (freezing time more than 30 min). For example, after 8 months of storage at —20° F, quick-frozen, vacuum-packed, blue crab meat was highly acceptable when compared with fresh, refrigerated meat. At 0° F storage temperature, a noticeable drop in quality occurred during storage, especially if the product was not vacuum-packed. However, vacuum-packed frozen crab meat of high initial quality can be stored at 0° F for at least 8 months and still be comparable in quality to heat-pasteurized crab meat that has been stored at 34° F for the same time.

The rate of freezing blue crab meat has a significant effect on preserving its desirable qualities. Using spraying or immersion techniques based on Freon 12, freezing was accomplished in about 1 min and resulted in a product of very acceptable quality after storage and thawing. Slightly longer freezing rates were involved in some of the cryogenic nitrogen freezing methods. Although these freezing rates were less than 3 min, they resulted in products with a slightly lower acceptability. Even without considering the detrimental effects of slow freezing (30 min or more), it is obvious that the quality of frozen-stored blue crab meat is directly related to the rapidity of freezing it.

To extend the shelf life of frozen blue crab meat, it would be advisable to store it below 0°F, preferably as low as —20° F. Storage temperatures below —20° F offer further improvement in its storage stability but they are usually not as economically feasible as the higher temperatures. At 0° F storage temperature, a noticeable drop in quality can occur during storage, especially if proper attention is not given to considerations such as using only crab meat of high initial quality, quick freezing, vacuum packaging, and minimum storage periods.

The method of packaging had a noticeable influence on the storage stability of frozen crab meat. At 0° F storage temperature, vacuum packaging in a heat-sealed polyethylene-aluminum foil-mylar pouch resulted in a considerably

Table I-1.—Organoleptic evaluation of frozen-stored blue crab meat.

Type of meat	Method of freezing	Packaging used[1]	Results (9 point scale) after storing samples at indicated temperature and number of months[2]							
			0° F				−20° F			
			2	4	6	8	2	4	6	8
			Part 1. Overall taste results.							
Lump	Freon immersion	Bag	..	..	..	..	7.2	6.0	6.9	7.1
"	"	V. P.	..	..	..	..	..	..	..	7.4
"	"	Bag	5.5	3.7	..	..	..	..	..	..
"	"	V. P.	..	..	7.4	..	..	..	..	..
"[3]	"	V. P.	..	..	..	..	7.9	..	..	..
Flake	"	Bag	..	..	..	..	6.2	6.9	7.6	6.7
"	"	V. P.	..	..	..	..	6.6	6.2	..	6.9
"[4]	"	Bag	..	..	..	..	6.2	6.7	7.2	7.0
"	"	Bag	4.4	4.9	5.9	3.9	..	..	..	..
"	"	V. P.	6.9	5.9	6.3	6.0	..	..	..	..
"[3]	"	Bag	..	..	..	..	..	..	6.9	6.4
"[3]	"	V. P.	..	..	..	..	..	7.4	7.7	7.7
"[3]	"	V. P.	7.0	6.4	5.0	5.9	..	..	..	..
"	Freon spray	Bag	..	..	..	..	..	..	6.9	6.6
"	"	V. P.	..	..	..	..	..	..	..	7.0
Lump	LN immersion	V. P.	..	..	..	..	..	..	..	7.5
"	"	V. P.	..	..	6.7	6.8	..	..	..	..
"	"	V. P.	..	..	..	..	..	..	..	7.5
"	"	V. P.	..	..	6.6	6.4	..	..	..	..
Claw	"	V. P.	..	..	..	..	..	..	..	5.8
"	"	V. P.	..	..	6.1	6.2	..	..	..	..
Flake	Intermittent LN dipping	Bag	..	..	..	..	..	..	7.3	6.9
"	"	V. P.	..	..	..	..	..	..	..	7.0
"	N_2 blast NCG process	V. P.	..	..	..	..	..	7.0	6.2	..
"	Slow frozen[5]	Bag	..	..	..	..	..	..	6.4	5.4
"	"	V. P.	..	..	..	..	..	..	..	5.4
			Part 2. Odor results.							
Lump	Freon immersion	Bag	..	..	..	..	6.6	6.8	7.3	6.9
"	"	V. P.	..	..	..	..	..	..	..	7.5
"	"	Bag	5.4	4.9	..	..	..	..	..	..
"	"	V. P.	..	..	7.3	..	..	..	..	..
"[3]	"	V. P.	..	..	..	..	7.4	..	..	..
Flake	"	Bag	..	..	..	..	5.6	6.5	7.2	6.7
"	"	V. P.	..	..	..	..	6.3	6.4	..	6.7
"[4]	"	Bag	..	..	..	..	6.1	6.3	6.6	6.3
"	"	Bag	4.9	5.1	5.5	4.5	..	..	..	..
"	"	V. P.	6.7	6.1	6.8	6.0	..	..	..	..
"[3]	"	Bag	..	..	..	..	..	..	6.9	6.6
"[3]	"	V. P.	..	..	..	..	..	6.7	7.1	7.1
"[3]	"	V. P.	6.9	6.7	6.4	7.2	..	..	..	..
"	Freon spray	Bag	..	..	..	..	..	..	7.2	6.5
"	"	V. P.	..	..	..	..	..	..	..	7.3
Lump	LN immersion	V. P.	..	..	..	..	..	..	..	7.2
"	"	V. P.	..	..	7.1	6.8	..	..	..	..
"	"	V. P.	..	..	..	..	..	..	..	7.0
"	"	V. P.	..	..	7.2	7.3	..	..	..	..
Claw	"	V. P.	..	..	..	..	..	..	..	5.9
"	"	V. P.	..	..	6.4	6.0	..	..	..	..

See footnotes at end of table.

Table I-1.—Organoleptic evaluation of frozen-stored blue crab meat.—*Con.*

Type of meat	Method of freezing	Packaging used[1]	Results (9 point scale) after storing samples at indicated temperature and number of months[2]							
			0° F				−20° F			
			2	4	6	8	2	4	6	8
			Part 2. Odor results.—Con.							
Flake	Intermittent LN dipping	Bag	..	..	..	..	..	..	6.9	6.9
"	"	V. P.	..	..	..	..	..	..	..	6.7
"	N_2 blast NCG process	V. P.	..	..	..	..	..	6.6	6.0	..
"	Slow frozen[5]	Bag	..	..	..	..	..	..	6.2	5.9
"	"	V. P.	..	..	..	..	..	..	..	5.0
			Part 3. Texture results.							
Lump	Freon immersion	Bag	..	..	..	..	7.8	7.5	7.2	7.2
"	"	V. P.	..	..	..	..	..	..	..	7.9
"	"	Bag	7.0	5.4	..	..	..	..	..	..
"	"	V. P.	..	..	7.3	..	..	..	..	..
"[3]	"	V. P.	..	..	..	..	8.1	..	..	..
Flake	"	Bag	..	..	..	..	6.6	6.8	7.4	7.1
"	"	V. P.	..	..	..	..	6.6	6.5	..	6.7
"[4]	"	Bag	..	..	..	..	6.2	7.1	7.4	7.4
"	"	Bag	5.3	3.9	5.3	3.6	..	..	..	..
"	"	V. P.	6.6	5.8	5.8	5.5	..	..	..	..
"[3]	"	Bag	..	..	..	..	..	..	7.2	7.0
"[3]	"	V. P.	..	..	..	..	..	7.6	7.4	7.5
"[3]	"	V. P.	6.9	5.8	4.4	5.0	..	..	..	..
"	Freon spray	Bag	..	..	..	..	..	..	6.9	6.9
"	"	V. P.	..	..	..	..	..	..	..	7.4
Lump	LN immersion	V. P.	..	..	..	..	..	..	..	7.8
"	"	V. P.	..	..	7.1	6.9	..	..	..	..
"	"	V. P.	..	..	..	..	..	..	..	7.8
"	"	V. P.	..	..	7.3	6.5	..	..	..	..
Claw	"	V. P.	..	..	..	..	..	..	..	6.6
"	"	V. P.	..	..	6.0	5.7	..	..	..	..
Flake	Intermittent LN dipping	Bag	..	..	..	..	..	..	7.4	6.9
"	"	V. P.	..	..	..	..	..	..	..	6.9
"	N_2 blast NCG process	V. P.	..	..	..	..	..	7.0	6.1	..
"	Slow frozen[5]	Bag	..	..	..	..	..	..	6.7	6.1
"	"	V. P.	..	..	..	..	..	..	..	5.8
			Part 4. Appearance results.							
Lump	Freon immersion	Bag	..	..	..	..	7.9	7.9	7.7	7.6
"	"	V. P.	..	..	..	..	..	..	..	8.1
"	"	Bag	7.2	6.3	..	..	..	..	..	..
"	"	V. P.	..	..	7.7	..	..	..	..	..
"[3]	"	V. P.	..	..	..	..	8.1	..	..	..
Flake	"	Bag	..	..	..	..	5.9	6.1	7.1	6.9
"	"	V. P.	..	..	..	..	6.6	5.6	..	6.5
"[4]	"	Bag	..	..	..	..	5.3	6.3	5.8	6.0
"	"	Bag	5.0	5.5	5.5	5.2	..	..	..	..
"	"	V. P.	5.0	6.1	6.3	5.9	..	..	..	..
"[3]	"	Bag	..	..	..	..	..	..	6.9	7.1

See footnotes at end of table.

Table I-1.—Organoleptic evaluation of frozen-stored blue crab meat.—*Con.*

Type of meat	Method of freezing	Packaging used[1]	Results (9 point scale) after storing samples at indicated temperature and number of months[2]							
			0° F				−20° F			
			2	4	6	8	2	4	6	8
Part 4. Appearance results.—Con.										
Flake[3]	Freon immersion	V. P.	..	..	..	..	..	7.7	7.9	7.4
"	"	V. P.	7.5	5.0	5.7	7.4	..	..	..	..
"	Freon spray	Bag	..	..	..	..	..	..	7.3	6.9
"	"	V. P.	..	..	..	..	..	..	..	7.1
Lump	LN immersion	V. P.	..	..	..	..	..	..	..	7.8
"	"	V. P.	..	..	7.0	7.5	..	..	..	..
"	"	V. P.	..	..	..	..	..	..	..	7.1
"	"	V. P.	..	..	7.2	6.9	..	..	..	..
Claw	"	V. P.	..	..	..	..	..	..	..	5.9
"	"	V. P.	..	..	5.0	5.8	..	..	..	..
Flake	Intermittent LN dipping	Bag	..	..	..	..	..	..	6.7	7.1
"	"	V. P.	..	..	..	..	..	..	..	6.4
"	N_2 blast NCG process	V. P.	..	..	..	..	..	7.0	6.2	..
"	Slow frozen[5]	Bag	..	..	..	..	..	..	6.5	5.9
"	"	V. P.	..	..	..	..	..	..	..	6.0

[1] "Bag" refers to a polyethylene bag without vacuum while "V.P." refers to a three-ply laminate package heat-sealed while under vacuum.

[2] The rating system is outlined in Figure I-4. Based on 23 separate evaluations (295 individual ratings), the panel's average rating for overall taste was 6.8 and its range was 6.4 to 7.4 for fresh crab meat.

[3] Samples obtained from crabs caught near the Virginia coast (high-salinity water). Other samples from crabs caught in the Chesapeake Bay (low-salinity water).

[4] Sample thawed by microwave energy instead of ambient conditions for the organoleptic evaluation.

[5] Crab meat placed in package before freezing in still air at −20° F.

smaller quality drop during storage when compared with crab meat which was packed in unsealed but tightly closed polyethylene bags. This indicates that the quality changes of blue crab meat during frozen storage are caused primarily by oxidation effects. At −20° F storage temperature, these oxidative changes occurred at a much slower pace. Nevertheless, even at −20° F there was a noticeable quality difference between the vacuum-packed samples and the samples packed in unsealed polyethylene bags.

ACKNOWLEDGMENTS

John J. Powell and George M. Knobl, National Marine Fisheries Service, College Park, Md., provided facilities for part of the experimental work and shipped crab meat samples to FMC Laboratories during this investigation.

Financial support was received from the National Marine Fisheries Service under contract number 14-17-0007-968.

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Table I-2.—Organoleptic evaluation of preserved blue crab meat.

Type of meat	Method of preservation	Packaging used[1]	Storage conditions	Results (9 point scale) after storing samples for indicated number of months[2]			
				3	4	6	8
			Part 1. Overall taste results.				
Flake	Heat-pasteurized	V. P.	+34° F	6.8	6.9	..	6.7
Flake	Heat-sterilized	V. P.	+34° F	4.0	4.7	..	5.2
Flake	Freeze-dried	V. P.	Ambient temp.	..	..	4.9	..
Flake	Freon immersion	Bag	On dry ice	..	..	7.3	7.4
Lump[3]	Freon immersion	Bag	On dry ice	..	..	7.9	..
Flake[3]	Freon immersion	Bag	On dry ice	..	..	..	7.2
			Part 2. Odor results.				
Flake	Heat-pasteurized	V. P.	+34° F	6.5	6.3	..	6.0
Flake	Heat-sterilized	V. P.	+34° F	3.3	4.7	..	4.2
Flake	Freeze-dried	V. P.	Ambient temp.	..	..	5.9	..
Flake	Freon immersion	Bag	On dry ice	..	..	6.7	6.8
Lump[3]	Freon immersion	Bag	On dry ice	..	..	7.4	..
Flake[3]	Freon immersion	Bag	On dry ice	..	..	..	7.9
			Part 3. Texture results.				
Flake	Heat-pasteurized	V. P.	+34° F	6.9	6.8	..	7.1
Flake	Heat-sterilized	V. P.	+34° F	6.0	5.0	..	5.4
Flake	Freeze-dried	V. P.	Ambient temp.	..	..	6.1	..
Flake	Freon immersion	Bag	On dry ice	..	..	7.3	7.4
Lump[3]	Freon immersion	Bag	On dry ice	..	..	8.1	..
Flake[3]	Freon immersion	Bag	On dry ice	..	..	..	7.5
			Part 4. Appearance results.				
Flake	Heat-pasteurized	V. P.	+34° F	6.2	6.4	..	6.4
Flake	Heat-sterilized	V. P.	+34° F	1.7	2.7	..	2.9
Flake	Freeze-dried	V. P.	Ambient temp.	..	..	7.0	..
Flake	Freon immersion	Bag	On dry ice	..	..	6.3	7.1
Lump[3]	Freon immersion	Bag	On dry ice	..	..	7.9	..
Flake[3]	Freon immersion	Bag	On dry ice	..	..	..	7.4

[1] "Bag" refers to a polyethylene bag without vacuum while "V. P." refers to a three-ply laminate package heat-sealed while under vacuum.

[2] The rating system is outlined in Figure I-4. Based on 23 separate evaluations (295 individual ratings), the panel's average rating for overall taste was 6.8 and its range was 6.4 to 7.4 for fresh crab meat.

[3] Samples obtained from crabs caught near the Virginia coast (high-salinity water). Other samples from crabs caught in the Chesapeake Bay (low-salinity water).

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Blue Crab Meat
II. Effect of Chemical Treatments on Acceptability[1]

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ABSTRACT

Several chemical treatments were tested as adjuncts to preservation of blue crab meat. Most of these samples were preserved by freezing but some were heat-preserved or freeze-dried. In general, the dip treatments studied did not improve the quality of the preserved samples. However, glazing treatments with some of these chemical solutions appeared to improve the quality of frozen-stored samples.

INTRODUCTION

Meat from the blue crab (*Callinectes sapidus*) is an example of a commercially valuable product which is also highly perishable. Practically all of the present output is sold as fresh meat which has a shelf life of up to 10 days at 32° to 38° F. Although heat pasteurization is used occasionally to extend this shelf life (Byrd, 1951; Littleford, 1957), freezing is considered to have a great potential usefulness in preserving the desirable qualities of fresh crab meat over a period of several months (Strasser, Lennon, and King, 1971). Other results have led to the suggestion that chemical treatments such as the ones listed below may be a useful adjunct to preservation techniques such as freezing, pasteurization, or even freeze-drying.

Monosodium glutamate is widely known as a flavor enhancer in food products. It has been used to glaze frozen shrimp or as a dusting on shrimp just before freezing with beneficial results after 10 months' storage at 0° F (Norton, Tressler, Farkas, 1952). Lake herring fillets treated with a 2% solution of ascorbic acid and then glazed with a 1% solution of glutamate were of good quality through 12 months' storage at —5° F (Greig, Emerson, and Fliehman, 1967). In contrast, results of other investigations based on frozen shrimp (Commercial Fisheries Review, 1952) or oysters (Morton and Dyer, 1956; Osterhaug and Nelson, 1957) do not suggest that monosodium glutamate improves the quality of these stored products. It is conceivable that the variability of these results is related to different concentrations of monosodium glutamate used in these investigations since treatment of food products with monosodium glutamate before freezing can reduce the number of

[1] Portions of this report were presented at the 30th Annual Meeting of the Institute of Food Technologists, May 24-28, 1970.

viable bacteria obtainable from the frozen-stored product (Rojowska and Cyganska, 1966[2]).

Ascorbic acid has been used successfully to retard oxidative deterioration during frozen storage of several types of fish fillets (Anderson and Danielson, 1961; Bauernfeind, Smith, and Siemer, 1951; Greig, 1967a, 1967b; Greig et al., 1967) and to inhibit the blueing reaction in canned king crab meat (Groninger and Dassow, 1964). The results of other investigations suggest that treating shrimp (Faulkner and Watts, 1955), oysters (Osterhaug and Nelson, 1957; Pottinger, 1951), lobster meat (Dyer and Horne, 1953; Getchell and Highlands, 1957), or herring (Banks, 1951; Stansby and Dassow, 1963; Stansby, Pottinger, and Miyauchi, 1956) with ascorbic acid offers little or no improvement on the storage life of these frozen products. Since the effectiveness of ascorbic acid results from its sensitivity to oxidizing agents, its usefulness in extending shelf life is obviously related to the concentration remaining on a product after a dip or spray treatment and after a given set of frozen storage conditions. For this reason, it is conceivable that the difference in results between the cited investigations may be a result of different frozen storage conditions after a treatment with a dilute solution containing up to 1% ascorbic acid. On the other hand, antioxidants such as butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) have been used successfully in several food products because their effectiveness depends on a different chemical mechanism (Furia, 1968).

Condensed phosphates, salt, and citrate have been used on several occasions singularly, or in various combinations, as components of dips or glazes used to extend the shelf life of frozen-stored seafoods. Tripolyphosphate and pyrophosphate are examples of condensed phosphates which are used to inhibit textural deterioration or protein dehydration in frozen-stored fish fillets (Burt, Dreosti, Jones, Kelman, McDonald, Murray, Simmonds, and Stroud, 1968; Mahon, 1962; Murray 1967), canned tuna (U.S. General Services Administration, 1964), or canned king crab (Jones, 1968). Salt (usually sodium chloride) is usually included in a tripolyphosphate or a pyrophosphate solution to increase its effectiveness. Studies by Dyer, Brockerhoff, Hoyle, and Fraser (1964) and Hellendoorn (1962) demonstrate that the optimum concentration of each of these compounds is related to its ionic strength and the ionic strength of the fluid in the surface layer of a treated fillet. Sodium chloride alone has been used in solutions for treating Dungeness crab meat (Farber and Lerke, 1968), shrimp meat (Commercial Fisheries Review, 1952), lobsters (Getchell and Highlands, 1957), or fish fillets (Holston and Pottinger, 1955). Citric acid has been used to inhibit discoloration of crab meat (Dassow, 1950; Gangal and Magar, 1963; Stansby and Dassow, 1963). Treatment with a single acidified brine solution has already been suggested to inhibit textural deterioration and discoloration of Dungeness (Farber and Lerke, 1968), king (Dassow, 1950), and blue (Fellers and Harris, 1940) crab meat during subsequent storage.

Sodium nitrite is used as a preservative and color fixative in several meat products and in certain seafood products such as smoked-cured salmon, sable fish, and shad (Furia, 1968). The use of nitrite in crab meat has been proposed (U.S. General Services Administration, 1965). Since under certain storage conditions outgrowth of *Clostridium botulinum* in seafoods is theoretically possible (Johannsen, 1961; Perigo and Roberts, 1968), nitrite has been used occasionally as a bacterial growth inhibitor.

Although the chemicals listed above have been used in several applications for preserving seafoods, evidence is lacking concerning their suitability in preserving frozen blue crab meat even in contrast to heat-pasteurized, heat-sterilized, or chilled meat. On the other hand, there is definite evidence that factors such as: rate of freezing, method of packaging, and storage temperature and its duration have to be carefully controlled in order to preserve frozen blue crab meat for 2 to 8 months without any significant loss in the desirable qualities of freshly picked meat (Strasser et al., 1971). Consequently, the objective of the

[2] Rojowska, I., and R. Cyzanska, 1966. The influence of sodium glutamate on the bacterial count in frozen foods. Paper presented at the Second International Congress of Food Science and Technology, Warsaw, Poland.

present investigation is to determine if a chemical pretreatment affects the quality of preserved blue crab meat.

MATERIALS AND METHODS

Types of blue crab meat, methods of preservation by freezing, heating, or freeze-drying, methods of packaging, storage conditions, and methods of taste-panel evaluation are the same as described in Strasser et al. (1971). The 9-point rating scale used for the panel evaluations is given in Figure I-4.

The following two procedures were used with the various preservative solutions listed below.

Dipping Method

Preweighed crab meat was placed into a strainer, dipped into the preserving solution for 30 sec, and then allowed to drain for 90 sec before further processing (freezing, pasteurization, sterilization, or freeze-drying).

Spray (Glazing) Procedure

Just after freezing a sample of crab meat by immersion in food-grade Freon 12[3], it was spread out on a stainless steel screen. The spraying solution was sprayed on the sample from a Sprayon Jet Pack which was kept approximately 9 inches away from the sample. Spraying was done in a swaying action for about 15 sec (Fig. II-1). After another stainless steel screen was placed on top, the sample was turned over to spray the other side. Then the sample was refrozen by Freon immersion.

Chemical Preservative Solution Used

Monosodium glutamate.—An aqueous solution containing 2% monosodium glutamate was used for the dipping treatment and for glazing samples by the spray procedure.

Instead of dipping or spraying treatments, four crab meat samples received a dusting with monosodium glutamate powder. The meat was spread out on stainless steel screens and dusted over evenly with the powder before being frozen.

Ascorbic acid.—Although most of the crab meat samples treated with ascorbic acid were dipped in a 3% aqueous solution, a 1% solution was used for some of the samples. The 3% solution was also used to glaze several samples by the spray procedure. Two other samples were glazed using a 1% spray solution but this solution also contained 1% carboxymethylcellulose (a thickening agent) to give a better coating effect.

Condensed phosphates, salt, and citrate.—Two different phosphate compounds were used. One solution contained 10% sodium tripolyphosphate plus 2% sodium chloride. It was used for the dipping treatment and for glazing samples by the spray procedure. The other solution contained 2% sodium acid pyrophosphate alone, and it was used only for the dipping treatment. A third solution containing 5% sodium chloride and 1% sodium citrate was also used only for the dipping treatment.

Sodium nitrate.—An aqueous solution containing 1% sodium nitrite was used for the dipping treatment.

Tenox-6.—The spray procedure was used with a 3% solution of Tenox-6 in ethanol.

Figure II-1.—Spraying of crab meat with protective chemical solutions.

[3] Trade names are used to facilitate description; no endorsement of product is implied. The chemical name for Freon 12 is dichlorodifluoromethane.

Table II-1.—Organoleptic evaluation of blue crab meat treated with MSG before frozen storage.[1]

Type of meat	Method of freezing	Packaging used[3]	Overall taste results (9 point scale) after storing samples at indicated temperature and number of months[2]							
			0° F				−20° F			
			2	4	6	8	2	4	6	8
Flake	Freon immersion	Bag	..	..	..	..	6.8	6.1	6.6	7.1
"[4]	"	Bag	..	..	..	..	..	..	7.2	7.3
"	"	V. P.	..	..	..	..	..	..	..	6.7
"	"	Bag	5.4	5.1	5.1	4.7	..	..	..	..
"	"	V. P.	5.5	5.4	6.4	5.2	..	..	..	..
"[4]	"	V. P.	..	..	5.3	4.6	..	..	..	..
Lump	"	Bag	..	..	..	..	..	..	..	7.1
"	"	Bag	..	..	..	3.0	..	..	..	..
"	"	V. P.	..	..	7.1	..	..	..	..	..
Claw	"	V. P.	..	..	..	..	..	..	..	6.8
"	"	V. P.	..	..	6.1	5.7	..	..	..	..
Flake[a]	"	Bag	..	..	..	..	..	..	7.0	6.2
" [b]	"	V. P.	..	..	..	..	..	..	7.1	6.4
"	N_2 blast NCG process	V. P.	..	..	..	..	..	7.0	6.1	..

[1] Crab meat dipped in a 2% monosodium glutamate (MSG) solution before freezing except for samples, footnoted [a] and [b] in first column, which were dusted with dry MSG.

[2] The rating system is outlined in Figure I-4. Based on 23 separate evaluations (295 individual ratings), the panel's average rating for overall taste in fresh crab meat was 6.8 and its range was 6.4 to 7.4.

[3] "Bag" refers to a polyethylene bag without vacuum while "V.P." refers to a three-ply laminate package heat-sealed while under vacuum.

[4] Samples obtained from crabs caught near the Virginia coast (high-salinity water). Other samples from crabs caught in the Chesapeake Bay (low-salinity water).

Tenox-6 is a commercial food-grade antioxidant which according to the manufacturer, Eastman Chemical Products, Inc., Kingsport, Tenn., contains: 10% butylated hydroxyanisole (BHA), 10% butylated hydroxytoluene (BHT), 6% propylgallate, 6% citric acid, 12% propylene glycol, 28% corn oil, and 28% glyceryl monooleate.

Bacteriological Analyses

Difco Plate Count Agar was used in the total count determinations and Difco Violet Red Bile Agar was used in the coliform count determinations. Standard plate count techniques (including incubation at 37° C for 48 hr) were used for both determinations.

RESULTS AND DISCUSSION

Monosodium Glutamate Dips or Dusts

Panel evaluations of samples treated with monosodium glutamate before freezing are given in Table II-1 for samples held at 0° F or −20° F and in Table II-2 for samples held

Table II-2.—Organoleptic evaluation of blue crab meat frozen by Freon immersion and stored on dry ice.[1]

Chemical treatment	Overall taste results (9 point scale) after storing samples for indicated number of months[2]	
	6	8
2% sodium glutamate dip ...	7.5	7.4
1% ascorbic acid dip	7.0	7.4
3% ascorbic acid dip	5.3	4.7
Dip in 10% sodium tripolyphosphate plus 2% sodium chloride	5.9	6.5
2% sodium acid pyrophosphate dip	5.7	6.5
1% sodium nitrite dip	6.1	6.0
Dip in 1% sodium citrate plus 5% sodium chloride ..	5.8	5.8

[1] Flake meat samples dipped in indicated solution, frozen and packaged in a polyethylene bag.

[2] The rating system is outlined in Figure I-4. Based on 23 separate evaluations (295 individual ratings), the panel's average rating for overall taste in fresh crab meat was 6.8 and its range was 6.4 to 7.4.

on dry ice. Only the results for overall taste are presented in these tables since monosodium glutamate is known principally for its effect on the taste of foods and the ratings for appearance, odor, and texture on these samples were not significantly different from those received by control samples (Strasser et al., 1971).

It is quite evident from these results that the temperature of frozen storage is a more important consideration than the method of packaging for these storage periods. A comparison of these results with evaluations of samples which received the same freezing, packaging, and storage treatments but were not treated with monosodium glutamate (Strasser et al., 1971), suggests that treatment with this chemical did not significantly improve the taste of these samples.

Ascorbic Acid Dips

Panel evaluations of samples dipped in a 1% or a 3% solution of ascorbic acid before freezing are given in Table II-3 for samples held at 0° F or —20° F and in Table II-2 for samples held on dry ice. Although ratings for appearance, odor, and texture were also obtained, the results for overall taste presented in these tables are sufficient for this discussion.

In general, these ascorbic acid treatments depressed quality of the samples rather than enhanced it. Samples treated with ascorbic acid tended to receive the lowest ratings in comparison with samples which received other chemical treatments.

Table II-3.—Organoleptic evaluation of blue crab meat dipped in ascorbic acid solution before frozen storage.[1]

Type of meat	Method of freezing	Packaging used[3]	Overall taste results (9 point scale) after storing samples at indicated temperature and number of months[2]							
			0° F				—20° F			
			2	4	6	8	2	4	6	8
Flake	Freon immersion	Bag	..	..	..	..	4.0	5.3	6.8	6.9
"	"	V. P.	..	..	..	..	..	..	..	6.3
"	"	Bag	4.5	4.4	([4])	..	..	..	..	..
"	"	V. P.	5.8	4.9	..	..	..	..	..	..
"	"	Bag	..	..	..	..	5.3	4.6	5.0	5.6
"[5]	"	Bag	..	..	..	..	..	..	5.3	6.0
"	"	V. P.	..	..	..	..	..	..	..	5.2
"	"	Bag	3.7	3.6	..	..	..	..	..	..
"	"	V. P.	4.2	4.1	..	..	..	..	..	..
"[5]	"	V. P.	..	..	4.9	3.6	..	..	..	..
Lump	"	Bag	..	..	..	..	..	..	..	7.2
"	"	V. P.	..	..	6.8	..	..	..	..	..
Claw	"	Bag	..	..	..	..	..	..	..	6.4
"	"	V. P.	..	..	5.5	..	..	..	..	..
Flake	Freon spray	Bag	..	..	..	..	..	..	4.9	5.5
"	"	V. P.	..	..	..	..	..	..	..	6.1
"	Intermittent LN dipping	Bag	..	..	..	..	..	..	6.0	5.8
"	"	V. P.	..	..	..	..	..	..	..	7.1
"	N_2 blast NCG process	V. P.	..	..	..	..	..	4.7	4.7	..
"	Slow frozen[6]	Bag	..	..	..	..	..	..	4.9	4.9
"	"	V. P.	..	..	..	..	..	..	..	5.3

[1] First four samples dipped in 1% ascorbic acid solution; other samples dipped in 3% ascorbic acid solution.

[2] The rating system is outlined in Figure I-4. Based on 23 separate evaluations (295 individual ratings), the panel's average rating for overall taste in fresh crab meat was 6.4 to 7.4.

[3] "Bag" refers to a polyethylene bag without vacuum while "V.P." refers to a three-ply laminate package heat-sealed while under vacuum.

[4] Not tasted because of poor appearance and off-odor.

[5] Samples obtained from crabs caught near the Virginia coast (high-salinity water). Other samples from crabs caught in the Chesapeake Bay (low-salinity water).

[6] Crab meat placed in package before freezing in still air at —20° F.

Condensed Phosphate, Salt, and Citrate Dips

Panel evaluations for overall taste of samples dipped in a solution containing 10% sodium tripolyphosphate plus 2% sodium chloride, or in a solution containing 2% sodium acid pyrophosphate, or in a solution containing 5% sodium chloride plus 1% sodium citrate before freezing are given in Table II-4 for samples held at 0° F or —20° F and in Table II-2 for samples held on dry ice. Since it was anticipated that the use of these solutions would affect texture of the stored samples, results of the texture evaluations are presented in Table II-5.

These treatments produced mixed results. The samples which had been treated with tripolyphosphate plus salt or salt plus citrate were usually rated lower than untreated samples because of a pronounced salty taste. Samples treated with sodium acid pyrophosphate alone received slightly higher ratings for texture as well as overall taste. However, all three of these chemical treatments resulted in lower ratings compared with untreated frozen-stored samples (Strasser et al., 1971).

Employment of these chemicals was based on current theory concerning their effect on the functional properties of fish muscle proteins (Dyer, 1969). On the basis of this theory, it was assumed that these chemical treatments would be effective by producing an ionic strength in the order of 0.3 to 0.4 in the surface layer of the crab meat samples. From the results actually obtained, it is suggested that this assumption may be erroneous for blue crab meat (and possibly for other invertebrate food species). Obviously, some direct evidence is needed on the composition of crab muscle proteins and their extractability from raw and cooked crab meat.

Sodium Nitrite Dips

Panel evaluation of overall taste for samples dipped in a 1% sodium nitrite solution before freezing are given in Table II-6 for samples

Table II-4.—Organoleptic evaluation of blue crab meat treated with phosphate, citrate, and salt before frozen storage: overall taste results.[1]

Chemical treatment[3]	Packaging used[4]	Overall taste results (9 point scale) after storing samples at indicated temperature and number of months[2]							
		0° F				—20° F			
		2	4	6	8	2	4	6	8
TPP-NaCl	Bag	..	..	..	..	6.0	6.1	5.9	6.2
" [5]	Bag	..	..	..	..	..	..	6.7	6.9
"	V. P.	..	..	..	..	..	..	..	5.3
"	Bag	4.1	4.4	4.7	4.2	..	..	..	..
"	V. P.	5.8	5.9	4.4	4.9	..	..	..	..
" [5]	V. P.	..	..	6.1	6.1	..	..	..	..
SAPP	Bag	..	..	..	..	6.7	6.6	6.1	6.1
"	V. P.	..	..	..	..	..	..	..	7.1
"	Bag	5.5	5.0	4.7	5.2	..	..	..	..
"	V. P.	6.5	6.2	4.8	5.2	..	..	..	..
NaCl-citrate	Bag	..	..	..	..	5.5	5.6	5.9	6.1
"	V. P.	..	..	..	..	..	..	..	6.2
"	Bag	4.7	5.0	4.0	3.0	..	..	..	..
"	V. P.	5.6	4.8	5.1	4.4	..	..	..	..

[1] Flake meat samples frozen by immersion in Freon 12.

[2] The rating system is outlined in Figure I-4. Based on 23 separate evaluation (295 individual ratings), the panel's average rating for overall taste in fresh crab meat was 6.4 to 7.4.

[3] Crab meat dipped in a solution containing 10% sodium tripolyphosphate (TPP-NaCl) or in a solution containing 2% sodium acid pyrophosphate (SAPP) or in a solution containing 5% sodium chloride plus 1% sodium citrate (NaCl-citrate) before freezing.

[4] "Bag" refers to a polyetheylene bag without vacuum while "V.P." refers to a three-ply laminate package heat-sealed while under vacuum.

[5] Samples obtained from crabs caught near the Virginia coast (high-salinity water). Other samples from crabs caught in the Chesapeake Bay (low-salinity water).

Table 5.—Organoleptic evaluation of blue crab meat treated with phosphates, citrate, and salt before frozen storage: texture results.[1]

Chemical treatment[3]	Packaging used[4]	Texture results (9 point scale) after storing samples at indicated temperature and number of months[2]									
		0° F				—20° F				Dry ice	
		2	4	6	8	2	4	6	8	6	8
TPP-NaCl	Bag	..	..	..	..	6.4	6.3	6.5	6.6	..	..
" [5]	Bag	..	..	..	..	..	..	7.4	7.7	..	..
"	V. P.	..	..	..	..	..	..	..	6.4	..	..
"	Bag	5.6	5.8	5.5	5.4	..	..	..	..	..	..
"	V. P.	5.4	5.7	5.4	4.9	..	..	..	..	..	..
" [5]	V. P.	..	..	6.4	5.3	..	..	..	..	..	..
"	Bag	..	..	..	..	..	..	..	..	6.9	7.5
SAPP	Bag	..	..	..	..	6.7	6.8	6.4	6.6	..	..
"	V. P.	..	..	..	..	..	..	..	7.1	..	..
"	Bag	6.3	4.6	4.8	5.8	..	..	..	..	..	..
"	V. P.	6.7	6.2	5.0	5.2	..	..	..	..	..	..
"	Bag	..	..	..	..	..	..	..	..	7.5	7.0
NaCl-citrate	Bag	..	..	..	..	6.3	6.6	6.9	6.9	..	..
"	V. P.	..	..	..	..	..	..	..	7.3	..	..
"	Bag	5.6	5.3	3.7	3.9	..	..	..	..	..	..
"	V. P.	5.3	6.1	4.6	5.0	..	..	..	..	..	..
"	Bag	..	..	..	..	..	..	..	..	6.5	7.0

[1] Flake meat samples frozen by immersion in Freon 12.

[2] The rating system is outlined in Figure I-4.

[3] Crab meat dipped in a solution containing 10% sodium tripolyphosphate plus 2% sodium chloride (TPP-NaCl) or in a solution containing 2% sodium acid pyrophosphate (SAPP) or in a solution containing 5% sodium chloride plus 1% sodium citrate (NaCl-citrate) before freezing.

[4] "Bag" refers to a polyethylene bag without vacuum while "V.P." refers to a three-ply laminate package seat-sealed while under vacuum.

[5] Samples obtained from crabs caught near the Virginia coast (high-salinity water). Other samples from crabs caught in the Chesapeake Bay (low-salinity water).

held at 0° F or —20° F and in Table II-2 for samples held on dry ice. Ratings for appearance, odor, and texture were also made on these samples, but these results did not change as much as the overall taste rating.

Taken as a group, these results indicate that the nitrite dip treatment had a neutral effect on the acceptability of these samples. These results are very similar to evaluations made of undipped samples which were frozen, packaged, and stored by similar methods (Strasser et al., 1971). On the other hand, the nitrite-treated samples which were frozen rapidly and stored at —20° F received much higher ratings than samples which were dipped in some of the other chemical solutions used in this investigation.

Various Combinations of Dip and Spray Solutions

Several crab meat samples were glazed with various spray solutions either after a dip treatment and freezing or merely freezing them. The solutions used and the results obtained after storing these samples at —20° F are summarized in Table II-7.

Apart from Tenox-6, which was the only non-aqueous solution used, the composition of the spray solution had relatively little effect on the ratings received by these samples. These ratings are also generally similar to ratings received by crab meat samples which were frozen and stored under similar conditions but had not been treated with chemical solutions (Strasser et al., 1971). Although only two samples were treated with sodium carboxymethylcellulose, which is known as a coating agent, it is conceivable that the slightly higher ratings of these samples may be related to a slight preference shown for vacuum-packaged crab meat frozen and stored under similar conditions except for chemical treatments (Strasser et al., 1971). Considering all of these results, it appears that a glazing treatment is at

Table II-6.—Organoleptic evaluation of blue crab meat dipped in 1% sodium nitrite solution before frozen storage.

Type of meat	Method of freezing	Packaging used[2]	Overall taste results (9 point scale) after storing samples at indicated temperature and number of months[1]							
			0° F				−20° F			
			2	4	6	8	2	4	6	8
Flake	Freon immersion	Bag	..	..	..	..	6.5	7.0	6.9	6.2
"[3]	"	Bag	..	..	..	..	..	..	7.0	7.0
"	"	V. P.	..	..	..	..	..	..	..	6.2
"	"	Bag	4.2	4.3	4.9	4.4	..	..	..	..
"	"	V. P.	6.6	4.7	4.3	4.5	..	..	..	..
"[3]	"	V. P.	..	..	4.5	3.6	..	..	..	..
Lump	"	Bag	..	..	..	..	..	..	..	7.4
"	"	Bag	..	..	..	5.2	..	..	..	..
"	"	V. P.	..	..	6.0	..	..	..	..	..
Claw	"	Bag	..	..	..	..	..	..	..	6.1
"	"	Bag	..	..	..	4.6	..	..	..	..
"	"	V. P.	..	..	5.8	..	..	..	..	..
Flake	Freon spray	Bag	..	..	..	..	..	..	6.1	5.8
"	"	V. P.	..	..	..	..	..	..	..	6.2
"	Intermittent LN dipping	Bag	..	..	..	..	..	..	6.3	6.8
"	"	V. P.	..	..	..	..	..	..	..	7.4
"	N_2 blast NCG process	V. P.	..	..	..	..	..	5.9	5.7	..
"	Slow frozen[4]	Bag	..	..	..	..	..	..	5.4	5.5
"	"	V. P.	..	..	..	..	..	..	..	5.4

[1] The rating system is outlined in Figure I-4. Based on 23 separate evaluations (295 individual ratings), the panel's average rating for overall taste was 6.4 to 7.4 for fresh crab meat.

[2] "Bag" refers to a polyethylene bag without vacuum while "V.P." refers to a three-ply laminate package heat-sealed while under vacuum.

[3] Samples obtained from crabs caught near the Virginia Coast (high-salinity water). Other samples from crabs caught in the Chesapeake Bay (low-salinity water).

[4] Crab meat placed in package before freezing in still air at −20° F.

least equivalent to vacuum-packaging in maintaining the initial quality of crab meat during frozen storage.

Glazing also improved the storage stability of crab meat samples that had received unfavorable treatments before freezing. This improvement was evident for frozen samples sprayed with ascorbic acid or tripolyphosphate-sodium chloride solutions compared with samples that had been dipped in these solutions before freezing and not glazed afterwards (Table II-7 versus Tables II-3 and II-4). However, samples that had been dipped in monosodium glutamate solution or a sodium nitrite solution before frozen-storage were more acceptable and the glazing treatments did not significantly improve their acceptability (Table II-7 versus Tables II-1 and II-6).

Comparison of Freezing with Other Preservation Methods

Several of the chemical solutions previously discussed were also used to dip fresh crab meat before preserving it by heat pasteurization, heat sterilization, or freeze-drying. These solutions are listed in Table II-8 together with the results of panel evaluations for overall taste after storing these samples for 2 to 8 months.

The acceptability of these samples was generally rated no better than the acceptability of similarly preserved and stored samples which were not treated with chemical additives (Strasser et al., 1971). Ratings for the heat-pasteurized samples in Table II-8 were usually between those obtained for frozen samples stored at −20° F and samples stored at 0° F

Table II-7.—Organoleptic evaluation of blue crab meat treated with various dip and spray solutions.[1]

Composition of dip solution	Composition of spray solution	Packaging used[2]	Overall taste results (9 point scale) after storing samples at −20° F for indicated number of months[3]	
			6	8
2% monosodium glutamate[4]	1% ascorbic acid plus 1% sodium carboxymethylcellulose	Bag	6.7	7.2
"	3% ascorbic acid	Bag	5.8	6.8
"	"	V. P.	6.0	7.1
"	10% sodium tripolyphosphate plus 2% sodium chloride	Bag	6.6	6.7
"	"	V. P.	6.5	6.4
1% sodium nitrite	3% ascorbic acid	Bag	6.1	5.9
"	"	V. P.	6.5	6.5
None	2% monosodium glutamate	Bag	6.3	6.0
"	"	V. P.	6.8	6.4
"	3% ascorbic acid	Bag	6.6	6.1
"	3% Tenox-6	Bag	5.5	3.1
"	"	V. P.	5.6	3.9

[1] Flake meat samples dipped in solution indicated, frozen by immersion in Freon 12, then sprayed with solution indicated and refrozen by immersion in Freon 12.

[2] "Bag" refers to a polyethylene bag without vacuum while "V.P." refers to a three-ply laminate package heat-sealed while under vacuum.

[3] The rating system is outlined in Figure I-4. Based on 23 separate evaluations (295 individual ratings), the panel's average rating for overall taste in fresh crab meat was 6.8 and its range was 6.4 to 7.4.

[4] Samples obtained from crabs caught near the Virginia coast (high-salinity water). Other samples from crabs caught in the Chesapeake Bay (low-salinity water).

(Tables II-1, II-4, and II-6). None of the chemical treatments used appeared to improve the taste of the heat-sterilized samples even though sodium acid pyrophosphate and sodium nitrite treatments did improve their appearance. All of the freeze-dried samples received poor ratings.

SUMMARY AND CONCLUSIONS

In general, the chemical dip treatments did not improve the quality of preserved blue crab meat. Some of these dip treatments, such as ascorbic acid, actually depressed the quality of frozen-stored crab meat compared with untreated samples stored under similar conditions. Other dip treatments, such as monosodium glutamate or sodium nitrite, had a neutral effect. It is conceivable that the failure of these dip treatments to improve the quality of preserved crab meat may be due to unknown biochemical differences related to species or processing conditions between blue crabs and other crustaceans. Although these dip treatments may have leached some chemical constituents from the samples, the results of bacteriological examinations indicate that these samples were not significantly contaminated by these dip treatments (Table II-9).

When some of the same chemical solutions were used to glaze crab meat just after freezing it, an improvement in the quality of the frozen-stored samples was usually observed. All of

Table II-8.—Organoleptic evaluation of preserved blue crab meat.[1]

Chemical treatment[2]	Method of preservation	Overall taste results (9 point scale) after storing samples for indicated number of months[3]			
		2	4	6	8
2% sodium glutamate	Pasteurized	6.6	5.6	5.6	6.2
2% sodium acid pyrophosphate	"	6.4	7.1	5.0	5.8
1% sodium nitrite	"	..	6.8	5.1	5.9
1% sodium citrate plus 5% sodium chloride	"	6.4	6.3	6.7	2.9
2% sodium glutamate	Sterilized	4.4	5.9	6.4	5.1
2% sodium acid pyrophosphate	"	5.1	5.6	5.0	5.1
1% sodium nitrite	"	..	5.4	..	..
1% sodium citrate plus 5% sodium chloride	"	..	6.0	5.7	4.6
3% ascorbic acid	Freeze-dried	..	..	3.7	..
2% sodium acid pyrophosphate	"	..	..	4.7	..
2% Tenox-6 spray	"	..	..	4.4	..

[1] Vacuum-packed flake meat stored at 34° F (heat pasteurized and heat sterilized samples) or at ambient (room) temperature (freeze-dried samples).

[2] Meat samples dipped into solution indicated except last sample which received a spray of Tenox-6 solution.

[3] The rating system is outlined in Figure I-4. Based on 23 separate evaluations (295 individual ratings), the panel's average rating for the overall taste of fresh crab meat was 6.8 and its range was 6.4 to 7.4.

these samples were stored at —20° F, a storage temperature which is more suitable than 0° F to prolong the useful shelf life of crab meat for several months.

Since —20° F storage conditions are not always obtainable in commercial practice, an investigation of the merits of glazing cryogenically frozen crab meat for storage at 0° F appears worthwhile.

ACKNOWLEDGMENTS

John J. Powell and George M. Knobl, National Marine Fisheries Service, College Park, Md., provided facilities for part of the experimental work and shipped crab meat samples to FMC Laboratories during this investigation.

Financial support was received from the National Marine Fisheries Service under contract number 14-17-0007-968.

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Table II-9.—Results of bacteriological examinations on blue crab meat samples.

Preservation treatment[1]	Storage conditions		Bacterial counts per gram of sample	
	Temperature	Months	Total Count Agar	Violet Red Bile Ager
Not stored	Not stored	..	1,300	35
"	"	..	11,000	50
Frozen by Freon immersion	0° F	2	1,100	3,000
"	"	4	1,240	..
Heat pasteurized	+34° F	2	No growth	No growth
"	"	4	<100	..
Heat sterilized	+34° F	2	No growth	No growth
MSG dip	−20° F ([2])	0	51,000	70
"	+34° F ([3])	2	No growth	No growth
"	" "	4	<100/gram	
"	" ([4])	2	No growth	No growth
"	" "	4	No growth	
Ascorbic dip	−20° F ([2])	0	5,200	120
"	" "	2	4,900	<10/gram
"	" "	4	330	
"	0° F "	4	1,790	
TPP-NaCl dip	−20° F ([2])	0	32,000	1,000
"	" "	2	3,500	<10/gram
"	" "	4	2,010	
"	0° F "	4	3,200	
SAPP dip	−20° F ([2])	0	17,000	1,140
"	+34° F ([3])	2	No growth	No growth
"	" "	4	<100/gram	
"	" ([4])	2	No growth	No growth
"	" "	4	No growth	
Nitrite dip	−20° F ([2])	0	43,000	1,300
"	" "	2	14,500	200
"	" "	4	3,320	
"	0° F "	4	750	
NaCl-citrate dip	−20° F ([2])	0	25,000	120
"	" "	2	66,000	<10/gram
"	" "	4	4,100	
"	0° F "	4	540	
"	+34° F ([3])	2	No growth	No growth
"	" "	4	<100/gram	
"	" ([4])	2	No growth	No growth

[1] Description to abbreviations:
MSG = 2% monosodium glutamate solution
Ascorbic = 3% ascorbic acid solution
TPP-NaCl = Solution containing 10% sodium tripolyphosphate plus 2% sodium chloride
SAPP = 2% sodium acid pyrophosphate solution
Nitrite = 1% sodium nitrite solution
NaCl-citrate = Solution containing 5% sodium chloride and 1% sodium citrate

[2] Sample frozen by immersion in Freon 12 before storage.

[3] Sample heat-pasteurized before storage.

[4] Sample heat-sterilized before storage.

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GPO 998-388

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